AN EXPLORATIVE CFD STUDY ON STENOSIS-INDUCED FLOW INSTABILITIES IN THE CAROTID ARTERY

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1. INTRODUCTION

Flow bench studies on stenosed models embedded with tissue mimicking gels, e.g. Polyvinyl alcohol (PVA), demonstrate that stenosis-induced flow instabilities and pressure fluctuations may lead to mechanical waves which propagate through soft tissues and can be detected by means of non-invasive diagnostic tool such as laser Doppler vibrometry (LDV). Computational Fluid Dynamics (CFD) may provide a complementary tool to better understand stenosis flow related phenomena and provide insights into this diagnostic method.

2. MATERIALS AND METHODS

A CT scan of a carotid bifurcation allowed us to obtain a patient specific case, with a maximum area stenosis of 82% in the Internal Carotid Artery (ICA). The geometry was 3D printed in compliant material and later embedded with PVA cryogel to mimick neck's tissues. The model was tested by means of LDV and pressure transducers, located downstream of the stenosis, for multiple flow settings. The applied Reynolds numbers (Re) ranged between 550 and 1100. Initial CFD simulations were performed by means of a commercial fluid solver (Fluent, Ansys) on a 440K hexahedral grid through time-dependent 3D Large Eddy Simulations (LES). The Smagorinsky-Lilly constant (Cs) was set equal to 0 in order to nullify the viscosity added by the model. Bounded schemes were used for the momentum and for the transient formulation. In order to replicate in-vitro tests, the highest pulsatile flow was applied at the inlet by means of User Defined Function. Moreover, to mimic also the in-vivo conditions, the outflow boundary was set as 32% flow ratio for the ICA [1]. Particular attention was given to the choice of the computational time step size (** ms), which was set in order to both match the in-vitro sampling frequency and respect the Courant–Friedrichs–Lewy (CFL) condition.

3. RESULTS AND DISCUSSION

Pressure instabilities were observed downstream of the stenosis, where the flow diverges and decelerates. The amplitude of pressure oscillations was obtained by means of frequency analysis of the discrete signal (Fast Fourier Analysis, FFT). Highest frequency peaks were observed 2 to 4 diameters downstream of the stenosis, revealing peaks in the 10-450 Hz frequency band.

These initial CFD results are in line with previous studies with similar models and our own experimental observations. Further analysis will be performed at different flow rates, shape and degree of stenosis. The sensitivity of the results to the mesh density and to the time step will be further explored. The computational method and the in-vitro techniques are currently further investigated.

The integrated experimental-computational approach will provide further details on fluid dynamics and mechanical phenomena, providing subsequently guidance for studies on patients.

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References

[1] Harald C.G. et al., J Biomech, 43:2332-2338, 2010. [2] Sherwin A.J. et al., J Fluid Mech, 533:297-327, 2005.